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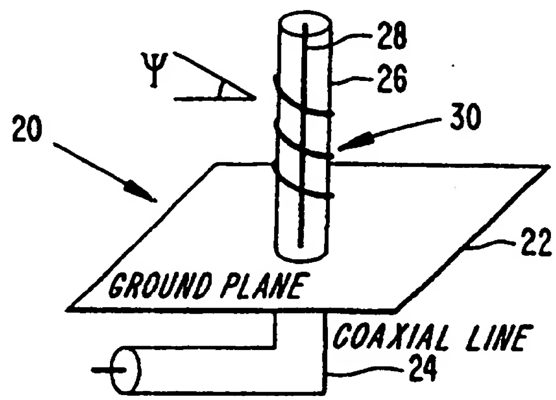
(54) Title: COAXIAL DUAL-BAND ANTENNA

(57) Abstract

An electromagnetic antenna (20, 30) that is compact and easy to manufacture includes a portion of a coaxial cable (24) having a first predetermined electrical length, the cable's outer conductor (22) being removed from the portion for forming an electromagnetic monopole (28), a parasitic element (30) including a conductor spirally wound around the dielectric material (26) of the portion, the parasitic element having a second predetermined electrical length, and an electrical ground plane (22) disposed in an electromagnetically cooperative relationship with the portion and the parasitic element. The parasitic element may be secured with an adhesive to the dielectric material of the portion, and the first predetermined length may be substantially one quarter of a first predetermined wavelength and the second predetermined length may be substantially one half of a second predetermined wavelength. In particular, the first predetermined length may be 9.4 centimeters and the second predetermined length may be 7.9 centimeters. Also, the electrical ground plane may be disposed substantially perpendicular to the portion and the parasitic element, and the pitch angle of the parasitic element windings may be varied for generating selected spatial patterns of electromagnetic field intensity and power density. Methods of making an electromagnetic antenna from a coaxial cable are also disclosed.



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COAXIAL DUAL-BAND ANTENNA

BACKGROUND

This invention relates to antennas for electromagnetic signals and more particularly to such antennas that have coaxial elements.

With the advent of multiple wireless communication systems that operate simultaneously in different frequency ranges, such as the Advanced Mobile Phone Service (AMPS) system that uses carrier signals having frequencies around 800 megahertz (MHZ) and the Personal Communication Services (PCS) system that uses carrier signals having frequencies around 1900 MHZ, there has arisen a need for a transceiver having the ability to function in both systems.

One approach to this problem is to provide the transceiver with two separate antennas, each optimized for signals in a respective one of the frequency bands. Such a two-antenna approach produces a transceiver that is unacceptably bulky and not aesthetically pleasing. Accordingly, it is desirable for such a transceiver to have a compact, single antenna that operates in two frequency bands.

One way of constructing a dual-band antenna is to place a parasitic element having an electrical length $\lambda_1/2$ in close proximity to a linear antenna having an electrical length $\lambda_0/2$. Such a dual-band antenna 10 is illustrated in Fig. 1. The parasitic element 12, which is not physically connected to the transceiver (not shown), is resonant at a frequency $f_1 = c/\lambda_1$, and the linear antenna 14, which is illustrated as a dipole and is physically connected to the transceiver, is resonant at a frequency $f_0 = c/\lambda_o$, where c is the speed of light.

At their respective resonance conditions, the parasitic element 12 and the linear antenna 14 efficiently couple energy into and out of the surrounding medium, e.g., free space. The parasitic element, since it is not resonant at frequency f_0, is substantially transparent to the operation of the linear antenna, and the linear antenna, since it is not resonant at frequency f_1, is substantially transparent to the operation of the parasitic element. Since the parasitic element is resonant at the higher frequency f_1 and within suitably close proximity to the linear antenna, energy at f_1 is efficiently coupled to and

from the linear antenna and the surrounding medium. Hence. a dual-band response. i.e.. simultaneous optimal energy coupling at both f_0 and f_1, is achieved.

The efficiency of the antenna's energy coupling can be illustrated by a plot of the voltage standing wave ratio (VSWR) with respect to frequency. Fig. 2 depicts a typical response of a dual-band antenna such as that shown in Fig. 1. The two regions of low VSWR correspond to the resonance conditions at the frequencies f_0, f_1.

One of the problems with the kind of dual-band antenna shown in Fig. 1 is that it is difficult to manufacture. In particular, the separation between the linear antenna and the parasitic element must typically be maintained with a precision on the order of twenty-five micrometers, or one-thousandth of an inch. Such precisions are difficult and costly to achieve. Accordingly, it is desirable for a dual-band antenna to be easy and cheap to manufacture.

SUMMARY

This invention solves the problems of the prior devices and provides an electromagnetic antenna that is not only compact but also easy to manufacture. In one aspect of the invention, a method of making an electromagnetic antenna from a coaxial cable having an outer conductor, a dielectric material, and an inner conductor, the inner conductor being disposed in the dielectric material, comprises the steps of: stripping the outer conductor from a portion of the coaxial cable, thereby exposing the dielectric material; spirally winding a parasitic conductor on the exposed dielectric material; and disposing the portion and the parasitic conductor in an electromagnetically cooperative relationship with an electrical ground plane. The portion has a first predetermined electrical length and the parasitic conductor has a second predetermined electrical length.

In other aspects of the invention, the method may further comprise the step of securing the parasitic conductor to the dielectric material with an adhesive. Also, the first predetermined length may be substantially one quarter of a first predetermined wavelength and the second predetermined length may be substantially one half of a second predetermined wavelength. In particular, the first predetermined length may be

9.4 centimeters and the second predetermined length may be 7.9 centimeters. Furthermore, the portion and the parasitic conductor may be disposed substantially perpendicular to the electrical ground plane, and the method may further comprise the step of selectively controlling an amount of coupling between windings of the parasitic conductor by varying a pitch angle of the windings, thereby producing a parasitic conductor having selected spatial patterns of electromagnetic field intensity and power density.

In another aspect of the invention, an electromagnetic antenna comprises a portion of a coaxial cable having a first predetermined electrical length, the coaxial cable having an outer conductor, a dielectric material, and an inner conductor disposed within the dielectric material. The outer conductor is removed from the portion for forming an electromagnetic monopole. The antenna further comprises a parasitic element comprising a conductor spirally wound around the dielectric material of the portion, and the parasitic element has a second predetermined electrical length. The antenna also comprises an electrical ground plane disposed in an electromagnetically cooperative relationship with the portion and the parasitic element.

In other aspects of the invention, the parasitic element may be secured with an adhesive to the dielectric material of the portion, and the first predetermined length may be substantially one quarter of a first predetermined wavelength and the second predetermined length may be substantially one half of a second predetermined wavelength. In particular, the first predetermined length may be 9.4 centimeters and the second predetermined length may be 7.9 centimeters. Also, the electrical ground plane may be disposed substantially perpendicular to the portion and the parasitic element, and a pitch angle of the parasitic element's windings may be varied for generating selected spatial patterns of electromagnetic field intensity and power density.

BRIEF DESCRIPTION OF THE DRAWINGS

Applicants' invention will be understood by reading this description in conjunction with the drawings in which:

Fig. 1 illustrates a conventional dual-band antenna;

Fig. 2 is a plot of voltage standing wave ratio with respect to frequency for the dual-band antenna depicted in Fig. 1;

Fig. 3A illustrates a coaxial monopole antenna in accordance with Applicants' invention;

Fig. 3B illustrates a dual-band antenna in accordance with Applicants' invention;

Fig. 4 is a plot of voltage standing wave ratio with respect to frequency for the dual-band antenna depicted in Fig. 3B; and

Fig. 5 illustrates a dual-band antenna having a parasitic element that comprises a number of sections having small pitch angle separated by sections having large pitch angle.

DETAILED DESCRIPTION

Applicants' invention solves the manufacturabilty problem of previous dual-band antennas by taking advantage of the precision with which coaxial transmission lines are commercially manufactured. The dimensions of coaxial cables such as RG-59, RG-62, RG-116, etc. have suitable precisions. As explained in more detail below, the inner conductor of the coaxial cable forms a linear radiating structure having an electromagnetic length such that it is resonant at a first frequency f_0.

Figs. 3A, 3B depict one preferred embodiment of the invention, a monopole antenna 20 above a ground plane 22. Referring to Fig. 3A, an insulating sheath and an outer conductor of a coaxial cable 24 are removed to expose the cable's cylindrical, dielectric core 26, within which the line's inner conductor 28 is disposed. The outer conductor of the coaxial line 24 may be connected electrically to the ground plane 22, which might be an electrically conductive case of a radio transceiver such as a hand-held radiotelephone. It will be appreciated, however, that the ground plane may also be electrically insulated from the transceiver's case as described in U.S. Patent Application No. 08/274,450 filed on July 13, 1994, by Cassel and European Patent Publication No. EP 0 528 775 published on February 24, 1993, by Cassel, both of which are incorporated here by reference.

The exposed dielectric material 26 and embedded inner conductor 28 are trimmed such that a desired length protrudes above the ground plane 22, as illustrated in Fig. 3A. It will be appreciated that the arrangement depicted in Fig. 3A is a coaxial monopole antenna. The physical length protruding above the ground plane 22 is typically selected such that the electromagnetic length is an integer number of quarter-wavelengths $\lambda_0/4$ at the intended frequency f_0. When the electromagnetic length is one quarter-wavelength, the monopole may act like a half-wave antenna due to the electrical image of the protruding length formed in the ground plane 22. For example, the electromagnetic length protruding above the ground plane 22 would be approximately 9.4 centimeters (cm) for a frequency $f_0 = 800$ MHZ, assuming the ground plane and the protruding length were disposed substantially perpendicular to each other.

In further accordance with Applicants' invention, a parasitic element 30 such as a conductor is spirally wrapped around the dielectric cylinder as illustrated in Fig. 3B. The parasitic element may be a wire wrapped tightly enough for friction to retain it in position on the dielectric material, although alternatively such a parasitic element 30 may be retained by wrapping it in a groove in the surface of the dielectric cylinder or by applying a suitable adhesive material. Instead of a wire, the parasitic element may be a conductive tape wrapped around the dielectric cylinder or even a conductive ink printed in a desired pattern on the dielectric cylinder. The parasitic element 30 merely needs to be a conductive element resonant at a desired frequency.

Based on a pitch angle Ψ and the physical length of the spirally wound parasitic element 30, the parasitic element can be made to have an electromagnetic length such that it resonates at a frequency f_1 that is different from the resonance frequency f_0 of the inner conductor 28. The antenna illustrated in Fig. 3B thus would have a dual-band response (at f_0 and f_1) and an expected VSWR response as shown in Fig. 4.

In contrast to the inner conductor 28, the electromagnetic length of the parasitic element 30 is typically selected to be an integer number of half-wavelengths $\lambda_1/2$ at its resonant frequency f_1. The electromagnetic length would typically be less than the physical length in order to compensate for the reduced propagation velocity of the electromagnetic field through the dielectric material 26 as compared to the surrounding

medium, e.g., free space. For example, the electromagnetic length of the parasitic element 28 would be approximately 7.9 cm for a frequency f_1 = 1900 MHZ without compensating for the reduced propagation velocity. The electromagnetic length of the parasitic element 30 is determined by its physical length and the dielectric constant of the dielectric cylinder 26.

It will be appreciated that the exact length of the parasitic element 30, as well as the length of the inner conductor 28, may be determined from the principles of antenna theory, although some minor adjustments might be needed to optimize the antenna response. In general, these principles would be applied with the boundary condition that the value of the electric current at the two ends of the parasitic element 30 (and at at least the distal end of the inner conductor 28) is zero. For example, it will be understood that the angle between the ground plane and the protruding cable portion and parasitic element affects the spatial distribution of electromagnetic field intensity and power density. Since the dimensions of the coaxial line's dielectric core 26 are well characterized and held to very close tolerances during manufacturing, Applicants' dual-band antenna can be manufactured consistently and inexpensively.

One factor affecting the electromagnetic length of a spirally wound parasitic element is the amount of electromagnetic coupling between the spiral windings. The amount of coupling is effectively determined by the pitch angle Ψ, which determines the distance between the windings. It is currently expected that minimizing this coupling will be desirable in some cases, and thus large pitch angles would be used; it is believed there would not be much coupling with a pitch angle of at least about forty-five degrees for frequencies around 1900 MHZ.

On the other hand, it is also currently expected that coupling will be desirable in some cases. As the spiral windings are brought closer together, the increased coupling, which is primarily capacitive for high frequencies, tends to increase the electromagnetic length of the parasitic element. Moreover, selectively controlling the amount of coupling by selectively controlling parameters such as the pitch angle and cylinder 26's dielectric constant permits selection of the electric current distribution along the parasitic element and of the directional pattern of the antenna at frequencies around f_1.

By varying the pitch angle along the length protruding above the ground plane, it should be possible to produce a parasitic element having spatial patterns of field intensity and power density that are more complex than those of a monopole. For example as depicted in Fig. 5, the pitch angle might be varied such that the parasitic element comprises a number of sections having high coupling (small pitch angle Ψ_2) separated by sections having little or no coupling (large pitch angle Ψ_1), thereby yielding an antenna pattern appropriate to a linear array of elements.

It will be appreciated that Applicants' invention also encompasses a dual-band antenna in which the spiral element 30 is excited and the linear element 28 is parasitic, although it is believed such an arrangement is not currently preferred due to relatively more complex impedance matching and difficulties in fabrication from coaxial cable. In such an antenna, the spiral element 30 would operate like a wound dipole and the length of the inner conductor 28 would need careful adjustment.

It will be understood by those of ordinary skill in the art that this invention can be embodied in other forms without departing from its essential nature. Therefore, the embodiments described above will be considered in all respects as illustrative and not restrictive. The scope of this invention is defined by the following claims.

WHAT IS CLAIMED IS:

1. A method of making an electromagnetic antenna from a coaxial cable having an outer conductor, a dielectric material, and an inner conductor, the inner conductor being disposed in the dielectric material, comprising the steps of:

stripping the outer conductor from a portion of the coaxial cable, thereby exposing the dielectric material;

spirally winding a parasitic conductor on the exposed dielectric material; and

disposing the portion and the parasitic conductor in an electromagnetically cooperative relationship with an electrical ground plane;

wherein the portion has a first predetermined electrical length and the parasitic conductor has a second predetermined electrical length.

2. The method of claim 1, further comprising the step of securing the parasitic conductor to the dielectric material with an adhesive.

3. The method of claim 1, wherein the first predetermined length is substantially one quarter of a first predetermined wavelength and the second predetermined length is substantially one half of a second predetermined wavelength.

4. The method of claim 3, wherein the first predetermined length is 9.4 centimeters and the second predetermined length is 7.9 centimeters.

5. The method of claim 1, wherein the portion and the parasitic conductor are disposed substantially perpendicular to the electrical ground plane.

6. The method of claim 1, further comprising the step of selectively controlling an amount of coupling between windings of the parasitic conductor by varying a pitch angle of the windings, thereby producing a parasitic element having selected spatial patterns of electromagnetic field intensity and power density.

7. An electromagnetic antenna, comprising:

a portion of a coaxial cable having a first predetermined electrical length, the coaxial cable having an outer conductor, a dielectric material, and an inner conductor disposed within the dielectric material, wherein the outer conductor is removed from the portion whereby the portion is an electromagnetic monopole;

a parasitic element comprising a conductor spirally wound around the dielectric material of the portion. wherein the parasitic element has a second predetermined electrical length; and

an electrical ground plane disposed in an electromagnetically cooperative relationship with the portion and the parasitic element.

8. The antenna of claim ⁻. wherein the parasitic element is secured with an adhesive to the dielectric material of the portion.

9. The antenna of claim 7, wherein the first predetermined length is substantially one quarter of a first predetermined wavelength and the second predetermined length is substantially one half of a second predetermined wavelength.

10. The antenna of claim 9, wherein the first predetermined length is 9.4 centimeters and the second predetermined length is 7.9 centimeters.

11. The antenna of claim 7, wherein the electrical ground plane is disposed substantially perpendicular to the portion and the parasitic element.

12. The antenna of claim 7, wherein a pitch angle of windings of the parasitic element varies for generating selected spatial patterns of electromagnetic field intensity and power density.

13. The antenna of claim 7, wherein the parasitic element is excited by an electrical signal.

Fig. 1
PRIOR ART

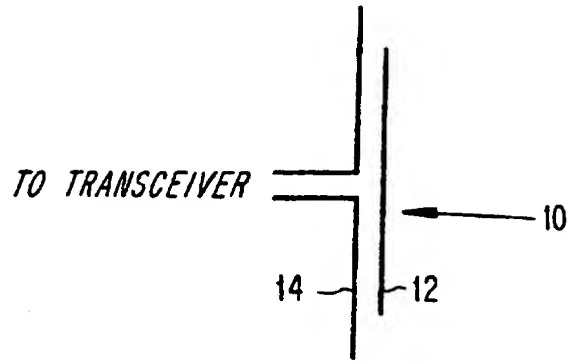
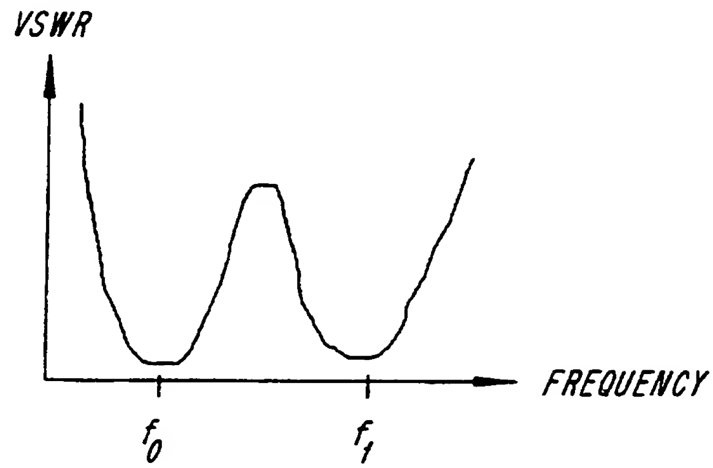


Fig. 2



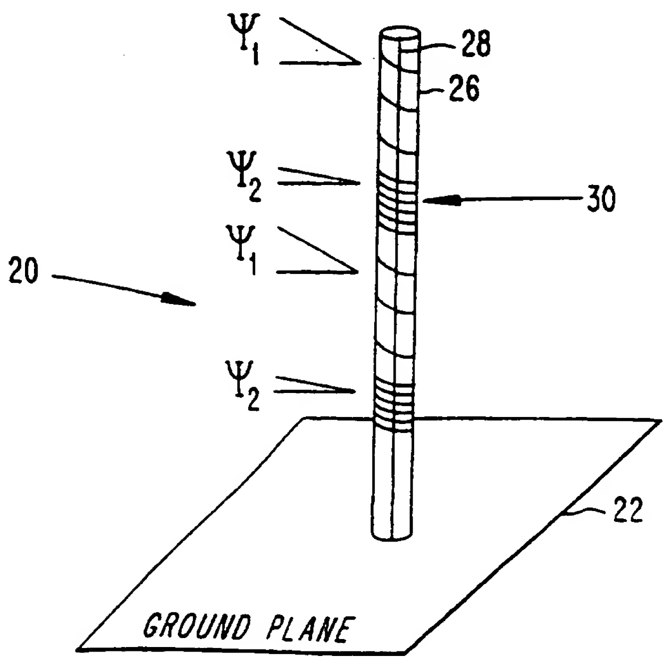


Fig. 5

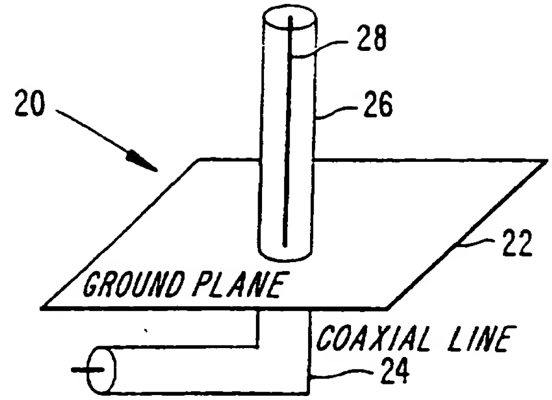


Fig. 3A

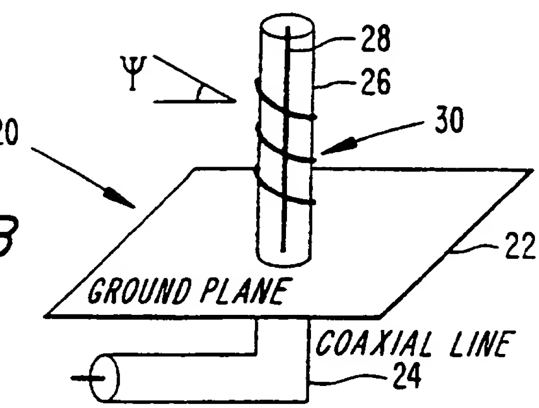


Fig. 3B

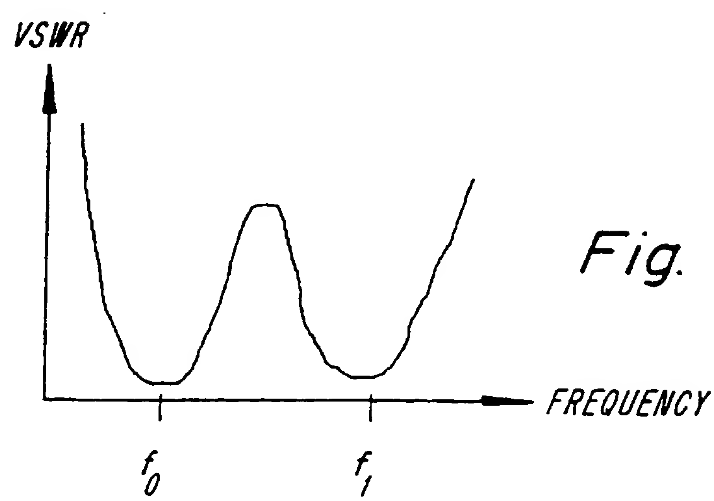


Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01Q5/00 H01Q9/30 H01Q1/36

According to International Patent Classification (IPC) or to both national classification and IPC

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	HAAPALA P ET AL: "DUAL FREQUENCY HELICAL ANTENNAS FOR HANDSETS" 1996 IEEE 46TH. VEHICULAR TECHNOLOGY CONFERENCE, MOBILE TECHNOLOGY FOR THE HUMAN RACE ATLANTA, APR. 28 - MAY 1, 1996, vol. 1, 28 April 1996, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 336-338, XP000594306 see the whole document	1,7
A	US 4 494 122 A (GARAY ET AL.) 15 January 1985 see column 3, line 6 - column 4, line 66; figures 3,4	1-13

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[X] Further documents are listed in the continuation of box C.

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